भारतीय मानक
Indian Standard

IS 335 : 2018

नए विद्युत रोधन तेल — विशिष्टि

(पाँचवाँ पुनरीक्षण)

New Insulating Oils — Specification

(Fifth Revision)

ICS 29.040

भारतीय मानक ब्यूरो
BUREAUOFINDIANSTANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली-110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.org.in www.standardsbis.in

September 2018

Price Group 6

Fluids for Electrotechnical Applications Sectional Committee, ETD 03

FOREWORD

This Indian Standard (Fifth Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Fluids for Electrotechnical Applications Sectional Committee has been approved by the Electrotechnical Division Council.

This standard, first published in 1953, was based on BS 148 : 1951 'Insulating oil for transformers and switchgear', issued by the British Standards Institution. It was revised in 1963 to bring the test methods in line with the practices in vogue. The second revision was undertaken in 1972 mainly to include oxidation test as given in IEC Pub 296 (1982) 'Specification for unused mineral insulating oils for transformers and switchgear'. The third revision was undertaken in 1983 to include an ageing test based on ASTM D 1934 : 1968 'Standard method of test for oxidative ageing of electrical insulating petroleum oils by open beaker method', issued by the American Society for Testing and Materials. Subsequently, the fourth revision was undertaken in 1993 to include amendments issued since the adoption of third revision and also a new method of test adopted for detection of oxidation inhibitor.

This standard is largely based on IEC 60296 : 2012. Main changes with regard to the fifth revision include: Only one class of oil has been replaced by three classes, namely Type I transformer oil (in line with IEC 60296), Type II transformer oil with higher viscosity max, values at 40°C and third low temperature switchgear oil, but a new concept, the lowest cold start energizing temperature, has been included; new properties have been added (that is sulphur content, gassing tendency, PCA, PCB and furan); values for properties have been revised, and test methods have been revised (that is acidity, corrosive sulphur and oxidation stability).

This standard also covers the requirements of inhibited mineral insulating oils which were earlier covered in IS 12463 : 1988. With the publication of this standard IS 12463 is superseded and hence shall be withdrawn.

For the maintenance and supervision of insulating oils conforming to this standard and used in transformers, switchgear and certain other similar oil immersed equipment, reference shall be made to IS 1866 : 2000 'Code of practice for maintenance and supervision of mineral insulating oil in equipment (*third revision*)'.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

NEW INSULATING OILS — SPECIFICATION

(Fifth Revision)

1 SCOPE

This standard covers specifications and test methods for unused mineral insulating oils. It applies to oil delivered to the agreed point and time of delivery, intended for use in transformers, switchgear and similar electrical equipment in which oil is required as an insulant and for heat transfer. These oils are obtained by distillation and refining of crude petroleum.

Oils with and without additives are both within the scope of this standard.

This standard is applicable only to unused mineral insulating oils.

Reclaimed oils are beyond the scope of this standard.

This standard does not apply to mineral oils used as impregnants in cables or capacitors.

NOTE — Mineral insulating oils complying with the requirements of this standard, of the same class and containing no additives (*see* **3.4**), are considered to be compatible with one another and can be mixed in any proportion. This does not apply to oils containing additives. Where the user wishes to mix such oils, a check is recommended to be made to ensure that the mixture meets the requirements of this standard.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in Annex A.

3 TERMINOLOGY

For the purposes of this standard, the following definitions shall apply:

3.1 Transformer Oil — Mineral insulating oil for transformers and similar electrical equipment where normal oxidation resistance is required.

3.2 Low Temperature Switchgear Oil — Mineral insulating oil for oil-filled switchgear for outdoor application in very cold climatic conditions.

3.3 Mineral Insulating Oil — Insulating oil obtained by refining, modifying and/or blending of petroleum products and other hydrocarbons.

NOTE — This does not include insulating liquids such as esters, synthetic aromatics or silicone fluids.

3.4 Additive — Suitable chemical substance which is deliberately added to a mineral insulating oil in order to improve certain characteristics.

NOTE — Examples include antioxidants, metal passivators, metal deactivators, gas absorbers, pour point depressants, electrostatic charging tendency depressants, anti-foam agents, refining process improvers, etc.

3.5 Antioxidant Additive — Additive incorporated in insulating oil that improve oxidation stability.

NOTE — A large number of additives which improve oxidation stability, including inhibitors, peroxide decomposers, metal passivators and metal deactivators are available and may be used in oils if declared (*see* **6.11.1** and **6.11.2**)

3.5.1 *Inhibitor* — Antioxidant additives of the phenolic– or amine-type, such DBPC and DBP described in IS 13631.

Note — DBPC = 2,6 di-tert-butyl-para-cresol, DBP = 2,6 di-tert-butyl-phenol.

3.5.2 *Other Antioxidant Additive* — Antioxidant additive of the sulphur or phosphorous type.

3.5.3 *Passivator* — Metal passivator additive used primarily as electrostatic charging depressant, but which may also improve oxidation stability.

NOTE — Metal passivators are sometimes described as metal deactivators or corrosion inhibitors.

3.6 Uninhibited Oil — Mineral insulating oil containing no inhibitor.

NOTE — No inhibitor means that the total inhibitor content is below the detection limit of 0.01 percent (*see* IS 13631).

3.7 Trace Inhibited Oil — Mineral insulating oil containing less than 0.08 percent of total inhibitor content as measured as per IS 13631.

3.8 Inhibited Oil — Mineral insulating oil containing a minimum of 0.08 percent and maximum of 0.4 percent of total inhibitor content as measured as per IS 13631.

3.9 Unused Mineral Insulating Oil — Mineral insulating oil not recycled as delivered by the supplier.

NOTES

1 Such an oil has not been used in, nor been in contact with electrical equipment or other equipment not required for manufacture, storage or transport. The manufacturer and supplier of unused oil will have taken all reasonable precautions to ensure that there is no contamination with polychlorinated biphenyls or terphenyls (PCB, PCT), used, reclaimed or

dechlorinated oil or other contaminants.

2 A blend of unused and recycled oil in any proportion is regarded as being recycled.

3.10 Recycled Oil — General term to encompass mineral insulating oils previously used in electrical equipment that has been subjected to re-refining or reclaiming (regeneration) off-site.

NOTES

1 The characteristics of recycled oil are heavily dependent on the crude from which it was refined, the original refining technique, the service history and the type of recycling process. Natural antioxidants originally present in the oil might have been depleted in service or removed by the recycling process.

2 Recycled oil is not appropriate for use in some applications.

3 Such recycled oils are often produced from mixtures of mineral insulating oils of different origins.

4 A blend of unused and recycled oils in any proportion is regarded as being recycled oil.

5 Due to local legislation, in some countries, it is advisable to categorize used electrical oil as waste oil and complete separation of handling of unused and used oils is required

4 PROPERTIES OF OIL

Characteristics are given in Table 1 and Table 2 . The list of IEC and/or IS for specific properties is given in Table 3 (informative).

4.1 Functional Properties

Properties of oil which have impact on its function as an insulating and cooling liquid.

NOTE — Functional properties include viscosity, density, pour point, water content, breakdown voltage and dielectric dissipation factor.

4.2 Refining and Stability

Properties of oil that are influenced by quality and type of refining and additives.

NOTE — These can include appearance, interfacial tension, sulfur content, acidity, corrosive sulphur, 2 -furfural and related compounds contents and stray gassing.

4.3 Performance

Properties that are related to the long-term behaviour of oil in service and/or its reaction to high electric stress and temperature.

NOTE — Examples include oxidation stability, gassing tendency and electrostatic charging tendency (ECT).

4.4 Health, Safety and Environment (HSE) Properties

Oil properties related to safe handling and environment protection.

NOTE — Examples can include flash point, density, PCA (polycyclic aromatics), PCB / PCT (polychlorinated biphenyls and terphenyls).

5 CLASSIFICATION, IDENTIFICATION, GENERAL DELIVERY REQUIREMENTS AND SAMPLING

5.1 Classification

5.1.1 *Classes*

For the purpose of this standard, mineral insulating oils are classified into three classes:

a) Type I Transformer oils,
b) Type II Transformer oils, and
c) Low temperature switchgear oil.

5.1.2 *Antioxidant Additive (Inhibitor) Content*

Transformer oils are classified into three groups, according to their content of antioxidant additive:

a) uninhibited transformer oils: marked with U,
b) trace inhibited transformer oils: marked with T, and
c) inhibited transformer oils: marked with I.

5.1.3 *Lowest Cold Start Energizing Temperature (LCSET)*

After the inhibitor marking, the LCSET shall be indicated.

Standard LCSET in this standard is –30°C; optionally, other LCSET can be selected according to Table 1.

5.2 Requirements

General requirements of this standard are given in Table 2.

Specific requirements are defined under **7**.

5.3 Miscibility

Unused insulating oils of the same class (*see* **5.1.1**), the same group (*see* **5.1.2**) and the same LCSET (*see* **5.1.3**) and containing the same types of additives are considered to be miscible and compatible with each other (*see* IS 1866).

5.4 Identification and General Delivery Requirements

Identification and general delivery requirements are as follows:

a) Oil is normally delivered in bulk, rail tank cars, tank containers or packed in drums or IBC (intermediate bulk containers). These shall be clean and suitable for this purpose to avoid any contamination.
b) Oil drums and sample containers shall carry at least the following markings:
   1) supplier's designation,
   2) classification (*see* **5.1**), and
   3) oil quantity.
c) As agreed to between the supplier and the

purchaser each oil delivery shall be accompanied by a document from the supplier specifying the supplier's designation, oil classification and compliance certificate.

NOTE — This standard may be traceable to a specific batch of oil processed.

d) The supplier shall declare the generic type of all additives, and their concentration in the cases of inhibitors and passivators.

5.4.1 *BIS Certification Marking*

The product may also be marked with the Standard Mark.

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations made thereunder. The details of conditions under which the License for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

5.5 Sampling

Sampling shall be carried out in accordance with the procedure described in IS 6855.

6 PROPERTIES, THEIR SIGNIFICANCE AND TEST METHODS

6.0 General

The properties, test methods and limits shall be in accordance with those given in Table 2 unless otherwise specified in the respective clause.

6.1 Viscosity

Viscosity influences heat transfer and therefore the temperature rise of the equipment. The lower the viscosity, the easier the oil circulates leading to improved heat transfer. At low temperatures the resulting higher viscosity of oil is a critical factor for the cold start of transformers with poor or no circulation of oil and therefore possible overheating at the hot spots, and negatively influence the speed of moving parts such as in power circuit breakers, switchgear, on load tap changer mechanisms, pumps and regulators.

The viscosity at the lowest cold start energizing temperature (LCSET) shall not exceed 1 800 mm^2/s for LCSET temperatures higher than –40°C (respectively 2 500 mm^2/s at –40°C, *see* Table 1). This lowest cold start energizing temperature (LCSET) for transformer oils is defined in this standard as being –30°C but other LCSET (*see* Table 1) can be agreed to between the supplier and the purchaser.

Low temperature switchgear oil should have a lower viscosity at LCSET: 400 mm^2/s, *Max*. Standard LCSET of low temperature switchgear oil is defined with –40°C but other LCSET may be agreed to between the supplier and the purchaser.

Viscosity shall be measured according to IS 1448 (Part 25), viscosity at very low temperatures according to IS 16084.

6.2 Pour Point

Pour point of mineral insulating oil is the lowest temperature at which the oil will just flow. It is recommended that the pour point should be minimum 10°C below the lowest cold start energizing temperature (LCSET). If a pour point depressant additive is used, this should be mentioned by the supplier to the user. Pour point shall be measured in accordance with IS 1448 (Part 10/Sec 2).

6.3 Water Content

A low water content of mineral insulating oil is necessary to achieve adequate break down voltage and low dissipation losses. To avoid separation of free water, unused insulating oil should have limited water content. Before filling the electrical equipment, the oil should be treated to meet the requirements of IS 1866. Water content shall be measured in accordance with IEC 60814.

6.4 Breakdown Voltage

Breakdown voltage of transformer oil indicates its ability to resist electrical stress in electrical equipment. Breakdown voltage shall be measured in accordance with IS 6792. The supplier shall demonstrate that after

Table 1 Maximum Viscosity and Pour Point of Transformer Oil at Lowest Cold Start Energizing Temperature (LCSET)

(*Clauses* 4, 5.1.3 *and* 6.1)

Sl No.	LCSET °C	Maximum Viscosity mm^2/s	Maximum Pour Point °C
(1)	(2)	(3)	(4)
i)	0	1 800	–10
ii)	–10	1 800	–20
iii)	–20	1 800	–30
iv)	–30	1 800	–40
v)	–40	2 500	–50

treatment to reduce particles, water and dissolved air by vacuum procedure (*see* note), the oil shall have a high dielectric strength (breakdown voltage >70 kV).

NOTE — This treatment referred to filtration of the oil at 60 °C by vacuum (pressure below 2.5 kPa) through a sintered glass filter (with a maximum pore size at 2.5 µm).

6.5 Dielectric Dissipation Factor (DDF)

Dielectric Dissipation Factor is measure for dielectric losses caused within the oil. DDF values above requirements of Table 2 can indicate contamination of the oil by polar contaminants or poor refining quality. DDF shall be measured in accordance with IS 16086 at 90°C. In case of dispute, IEC 60247 at 90°C should be used.

NOTE — By agreement between parties, DDF may be measured at temperatures other than 90 °C. In such cases the temperature of measurement should be stated in the report.

6.6 Appearance

A visual inspection of insulating oil (oil sample in transmitted light under a thickness of approximately 10 cm and at ambient temperature) indicates the presence of visible contaminants, free water or suspended matter.

6.7 Acidity

Unused mineral insulating oil should be neutral and free from any acidic compound. Acidity shall be measured following IEC 62021-1.

Table 2 General Specifications
(*Clauses* 4, 5.2, 6)

Sl No.	Property	Test Method	Limits		
			Type I Transformer Oil	Type II Transformer Oil	Low Temperature Switchgear Oil
(1)	(2)	(3)	(4)	(5)	(6)
A Function					
i)	Viscosity at 40°C	IS 1448 (Part 25)	12 mm^2/s, *Max*	15mm^2/s, *Max*	3.5 mm^2/s, *Max*
ii)	Viscosity at 0°C[1)]	IS 1448 (Part 25)	—	1 800 mm^2/s, *Max*	—
iii)	Viscosity at –30°C[1)]	IS 1448 (Part 25)	1 800 mm^2/s, *Max*	—	—
iv)	Viscosity at –40°C[2)]	IS 16084	—	—	400 mm^2/s, *Max*
v)	Pour point	IS 1448 (Part 10/Sec 2)	–40°C, *Max* To be based on LCSET refer Table 1[1)]	–10°C, *Max* To be based on LCSET refer Table 1[1)]	–60°C[1)], *Max*
vi)	Water content	IEC 60814	30 mg/kg [3)]/40 mg/kg [4)], *Max*		
vii)	Breakdown voltage	IS 6792	30 kV/70 kV [5)], *Min*		
viii)	Density at 20°C	IS 1448 (Part 16)	0.895 g/ml, *Max*		
ix)	DDF at 90°C	IS 16086	0.005, *Max*		
x)	Particle content	IS 13236	No general requirement[10)]		
B Refining/stability					
xi)	Appearance	—	Clear, free from sediment and suspended matter		
xii)	Acidity	IEC 62021-1	0.01 mg KOH/g, *Max*		
xiii)	Interfacial tension	ASTM D971	No general requirement[6)]		
xiv)	Total sulphur content	ISO 14596 or ASTM D4294[12)]	No general requirement		
xv)	Corrosive sulphur	DIN 51353	Not corrosive		
xvi)	Potentially corrosive sulphur	IS 16310	Not corrosive		
xvii)	DBDS	IS 16497 (Part 1)	Not detectable (< 5 mg/kg)		
xviii)	Inhibitors according to IS 13631/IEC 60666	IS 13631	(U) Uninhibited oil: not detectable (< 0.01%)		
			(T) Trace inhibited oil: < 0.08%		
			(I) Inhibited oils : 0.08% –0.40%		
			(*see* **3.6** to **3.8**)		
xix)	Metal passivator additives according to IS 13631/IEC 60666	IS 13631	Not detectable (< 5mg/kg), or as agreed upon with the purchaser		

Table 2 — (*Concluded*)

Sl No.	Property	Test Method	Limits		
xx)	Other additives		*See*[7]		
xxi)	2-Furfural and related compounds content	IS 15668	Not detectable (< 0.05 mg/kg) for each individual compound		
C Performance					
xxii)	Oxidation stability	IS 12422 (Method C) Test duration[11] (U) Uninhibited oil: 164 h (T) Trace inhibited oil: 332 h (I) Inhibited oil: 500 h	For oils with other antioxidant additives and mental passivator Additives (*see* **6.12**)		
a)	• Total acidity[9]	1.9.4 of IS 12422	1.2 mg KOH/g, *Max*		
b)	• Sludge[9]	1.9.1 of IS 12422	0.8%, *Max*		
c)	• DDF at 90°C[9]	1.9.6 of IS 12422	0.500 [9], *Max*		
xxiii)	Gassing tendency	IEC 60628, Method A	No general requirement [8]		
xxiv)	ECT	*See* **6.14**	No general requirement [8]		
D Health, Safety and Environment (HSE)					
xxv)	Flash point	IS 1448 (Part 21)	135°C, *Min*	135°C, *Min*	100°C, *Min*
xxvi)	PCA content	IP 346	3%, *Max*		
xxvii)	PCB content	IS 16082	Not detectable (< 2 mg/kg)		

[1] This is the standard LCSET for a transformer oil (*see* **6.1**) and can be modified depending on the climatic condition of each region. Pour point should be minimum of 10°C below LCSET.
[2] Standard LCSET for low temperature switchgear oil.
[3] For bulk supply
[4] For delivery in drums and IBC.
[5] After laboratory treatment (*see* **6.4**)
[6] Where it is used as general requirement, a limit of minimum 40 mN/m is recommended.
[7] The supplier shall declare the generic type of all additives and their concentrations in the case of antioxidant additives.
[8] To be agreed upon between supplier and purchaser.
[9] At the end of oxidation stability tests.
[10] Particle content in drums at the delivery of the oil can be agreed between supplier and customer based on a statistical reference at delivery.
[11] A DDF of maximum 0.020 after 2 h of oxidation (*see* IS 12422 or IEC 61125) can be used for application in EHV instrument transformers and bushings.
[12] In case of any dispute, ISO 14596 should be used.

6.8 Interfacial Tension (IFT)

Low IFT sometimes indicates the presence of polar compounds. IFT shall be measured in accordance with ASTM D971.

6.9 Sulphur Content

Different organo-sulphur compounds are present in mineral oils, dependent on the crude oil origin and the degree and type of refining. Refining reduces the content of sulphur and aromatic hydrocarbons. As some sulphur compounds have an affinity to metals, they may act as natural oxidation inhibitors but they may promote corrosion on metallic components in the system.

Sulphur content is a specific requirement of **7.1**.

Sulphur content shall be measured following ISO 14596 or ASTM D4294. In case of any dispute, ISO 14596 should be used.

6.10 Corrosive Sulphur and Potentially Corrosive Sulphur

Some sulphur compounds, for example mercaptans, are very corrosive to metal surfaces, that is steel, copper and silver (switchgear contacts) and shall not be present in new oil. Corrosive sulphur shall be measured following DIN 51353.

Some other sulphur compounds, for example dibenzyl disulphide (DBDS), may result in the deposition of copper sulphide (Cu_2S) in paper insulation, reducing its electrical insulation properties (*see* Annex B). This has resulted in several equipment failures in service.

IS 16310 provides the best currently available method to detect potentially corrosive sulphur compounds in oil. It applies only to oils that do not contain a metal passivator additive (declared or undeclared).

For passivator – containing oils (*see* **B-3**).

6.11 Additives (*see* **3.4**)

6.11.1 *General*

The generic type of all additives shall be declared in product data sheets and certificates of compliance. For antioxidant additives and passivators, their concentrations shall also be stated.

6.11.2 *Antioxidant Additives* (*see* **3.5**)

Antioxidants slow down the oxidation of oil and therefore the formation of degradation products such as oil sludge and acidity. It is useful to know whether and in what proportion antioxidant additive has been added in order to monitor additive depletion during service.

Additives that slow down the oxidation of mineral insulating oils include:

a) Inhibitors such as phenols and amines (*see* **3.5.1**). The most widely used inhibitors are DBPC and DBP (*see* **3.5.1**). Detection and measurement of DBPC and DBP shall be carried out in accordance with IS 13631. Test methods are not available for other types of inhibitors.

b) Other antioxidant additives such as sulphur and phosphor – containing compounds, for example organic polysulphides and di-thio-phosphates (*see* **3.5.2**). An antioxidant additive of this type is DBDS (*see* **6.10**), but it is not accepted as it is known to be corrosive to copper and will likely result in the oil failing the potentially corrosive sulphur test of IS 16310. Test methods are in preparation only for DBDS (*see* **6.21**) and not for other antioxidant additives of this type.

c) Metal passivators (*see* **6.11.3**).

6.11.3 *Metal Passivators*

Some of these additives form thin films on copper, preventing the catalytic effect of copper in oil and the formation of harmful copper sulphide deposits in paper by reaction with corrosive sulphur compounds contained in the oil. Some of them protect the oil from the catalytic action of metals and slow down the rate of oxidation of oil. Passivators therefore slow down the oxidation process according to IS 12422 as they passivate the surface of the catalyzing copper wire, thus leading to an optimistic result of the oxidation stability test. Some of them are also used to reduce the electrostatic charging tendency of oils (*see* **6.14**).

Three main types of benzotriazole derivatives are typically used as metal passivator additives: N - bis (2-Ethylhexyl)-aminomethyl-tolutriazole (TTAA), benzotriazole (BTA) and 5-methyl-1H-benzotriazole (TTA). Detection and measurement of these additives shall be according to IS 13631.

Several other compounds can be used as metal passivator additives, such as N,N -bis(2-Ethylhexyl)-1H-1,2,4-triazole-1 methanamine (TAA), diamino-diphenyldisulphide, nicotinic acid, hydroquinoline and other sulphur-based compounds, for which no test methods are available[2].

[2. Examples of commercially available TTAA and TAA are Irgamet 39© and Irgamet 30© respectively. This information is given for the convenience of users of this standard and does not constitute any endorsement of these products.]

6.11.4 *Pour Point Depressants*

These additives are used to improve the viscosity and pour point of oils at very low temperatures. Detection and measurement of the two main types of pour point depressant additives used (polynapthalenes and polymethacrylates) shall be according to IS 13631.

6.12 Oxidation Stability

Oxidation of oil gives rise to acidity and sludge formation. This can be reduced by using oils with a high oxidation stability leading to longer service life time by minimizing sludge deposition and maximizing insulation life. Oxidation stability is measured in accordance with IS 12422. There is an option for stricter limits for special applications . More stringent limits and/or additional requirements and tests may be specified, if required.

Test durations for oils containing inhibitors shall be as indicated in Table 2. Test duration for oils containing other antioxidant additives and metal passivators shall be 500 h.

Passivator-containing oils shall be tested for oxidation stability before the passivator additive has been added to the oil (when possible), using the test durations of Table 2.

6.13 Gassing Tendency

Gassing tendency of mineral insulating oil, that is the gas absorbing property of oil when subjected to corona partial discharges, is only necessary and important for special equipment like HV (high voltage) instrument transformers and bushings. It is a measure of the rate of absorption or evolution of gas into oil under prescribed laboratory conditions. Gas absorption properties are related to oil aromatic content. Gassing tendency is measured using IEC 60628 (Method A).

Gassing tendency is a specific requirement of **7.3**.

NOTE — Additives such as 1, 2, 3, 4-tetrahydronapthelene (tetralin), mono or dibenzyl toluene and others have been proposed to reduce the gassing tendency of some oils, but are

not described in IS 13631. Mono and dibenzyltoluene are described in IEC 60867.

6.14 Electrostatic Charging Tendency (ECT)

Electrostatic Charging tendency of oil is an important property for certain designs of HV and EHV transformers which have oil pumping rates that can give rise to the build-up of electrostatic charge. This can result in energy discharge causing transformer failure.

ECT testing is a specific requirement of **7.2**.

NOTE — A method to measure ECT is proposed by CIGRE Technical Brochure 170. ECT can be reduced by using metal passivator additives such as BTA and TTA.

6.15 Flash Point

The safe operation of electrical equipment requires an adequately high flash point that is measured in accordance with IS 1448 (Part 21) (Pensky-Martens closed cup procedure).

6.16 Density

In cold climates, density of oil shall be low enough to avoid the ice that results from the freezing of free water to float to the oil surface and possibly lead to fault conditions developing such as flashover of conductors. Density shall be measured in accordance with IS 1448 (Part 16).

6.17 Polycyclic Aromatics (PCA)

Some PCAs are classified to be carcinogens and therefore need to be controlled to an acceptable level in mineral insulating oil. PCAs are defined so as to be detectable by extraction with DMSO (Dimethylsulfoxide) under the conditions of IP 346.

NOTE — Acceptable limits of total or individual PCAs are specified in national and local regulations.

6.18 Polychlorinated Biphenyls (PCB)

Unused mineral insulating oil shall be free from PCB. The reference test method is IS 16082.

6.19 2-Furfural (2-FAL) and Related Compounds Content

2-FAL and related compounds in unused mineral insulating oils can result either from improper re-distillation after solvent extraction during refining or from contamination with used oil.

Unused insulating oils should have a low level of 2-FAL and related compounds; measurement shall be done according to IS 15668.

NOTE — "Related compounds" are: 5-hydroxy methyl-2-furfural (5HMF) 2-furfuryl alcohol (2FOL), 2-acetyl furan (2ACF) and 5-methyl-2-furfural (5 MEF).

6.20 Particle Content

Particles in unused mineral insulating oil may result from manufacturing, storage or handling of oil, and may affect its breakdown voltage (*see* **6.4**). Measurement shall be carried out according to IS 13236.

6.21 DBDS Content

This compound is corrosive at normal transformer operating temperatures and can produce copper sulphide. It therefore shall not be present in unused oil (*see* **6.10**). For the test method for measuring DBDS, *see* IS 16497 (Part 1).

6.22 Stray Gassing of Oil

Some oils can produce gases such as hydrogen, hydrocarbons and carbon oxides at low temperatures (< 120 °C) without thermal or electrical faults in a transformer, sometimes even without operational stress. This phenomenon could result in a high production of gases and a misinterpretation of DGA results.

NOTE — Methods to measure stray gassing are described in CIGRE Brochure 296 and ASTM D7150. Inhibited grades typically produce less stray gassing than uninhibited ones.

7 SPECIFIC REQUIREMENTS FOR SPECIAL APPLICATIONS

7.1 Higher Oxidation Stability and Low Sulphur Content

For transformers with higher operating temperatures or designed for extended service life, there may exist restricted limits after oxidation test [*see* IS 12422 (Method C)]. Mostly, such oil is inhibited (I).

a)	Total acidity	0.3 mg KOH/g, *Max*
b)	Sludge	0.05 percent, *Max*
c)	DDF at 90°C	0.050, *Max*
d)	Total sulphur content	0.05 percent, *Max* (before oxidation test)

7.2 Electrostatic Charging Tendency (ECT)

For equipment with high oil circulation speed (OF -or OD-cooled power transformers [IS 2026 (Part 2)]), as for example HV/DC transformers, a limit may be agreed between purchaser and manufacturer.

7.3 Gassing Tendency

For equipment with high electrical field stress or special design, gases formed when subjected to corona partial discharges (*see* **6.13**) shall be absorbed by the oil. Therefore the gassing tendency according to IEC 60628 shall be agreed upon between the supplier and the purchaser of the oil for such equipment.

NOTE — In Poland, a gassing tendency < 5 mm^3/min is used for equipment > 400 kV.

Table 3 List of International Standard and/or Indian Standard Numbers for the Specific Properties (Informative)

(*Clause* 4)

Sl No.	Characteristics	International Standard	Indian Standard	Identical
(1)	(2)	(3)	(4)	(5)
i)	Viscosity, @ 40°C, 0°C & @ –30°C,	ISO 3104	IS 1448 (Part 25)	No
ii)	Viscosity, @ –40°C	IEC 61868	IS 16084	Yes
iii)	Pour point	ISO 3016	IS 1448 (Part 10/Sec 2)	Yes
iv)	Water content	IEC 60814	Not available	No
v)	Breakdown voltage	IEC 60156	IS 6792	Yes
vi)	Density @ 20°C	ISO 3675	IS 1448 (Part 16)	Yes
vii)	Dielectric dissipation factor @ 90°C	IEC 61620	IS 16086	Yes
viii)	Particle content	IEC 60970	IS 13236	Yes
ix)	Appearance	—	IS 335	No
x)	Acidity	IEC 62021-1	Not available	No
xi)	Interfacial tension	ASTM D971	Not available	No
xii)	Total sulphur content	ISO 14596 or ASTN D4294	Not available	No
xiii)	Corrosive sulphur	DIN 51353	Not available	No
xiv)	Potentially corrosive sulphur	IEC 62535	IS 16310	Yes
xv)	Oxidation inhibitor content	IEC 60666	IS 13631	Yes
xvi)	Metal passivator additives	IEC 60666	IS 13631	Yes
xvii)	2-Furfural content and related	IEC 61198	IS 15668	Yes
xviii)	Oxidation stability	IEC 61125 Method C	IS 12422	Yes
xix)	Gassing tendency, mm^3/min	IEC 60628 Method A	Not available	No
xx)	Flash point, °C	ISO 2719	IS 1448 (Part 21)	Yes
xxi)	PCA content, percent	IP 346	Not available	No
xxii)	PCB content, ppm	IEC 61619	IS 16082	Yes
xxiii)	Sampling of mineral insulating oil	IEC 60475	IS 6855	Yes
xxiv)	DBDS	IEC 62697-1	IS 16497 (Part 1)	Yes
xxv)	Stray gassing	CIGRE Brochure 296 or ASTM D 7150	Not available	No
xxvi)	Electrostatic charging tendency	CIGRE Brochure 170	Not available	No
xxvii)	Foaming test	ISO 6247	Not available	No

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS/International Standard No.	*Title*
1448	Methods of test for petroleum and its products :
(Part 10/Sec 2) : 2013	Cloud point and pour point, Section 2 Determination of pour point (*second revision*)
(Part 16) : 2014	Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method (*fourth revision*)
(Part 21) : 2012	Determination of flash point — Pensky-martens closed cup method (*third revision*)
(Part 25) : 1976	Determination of kinematic and dynamic viscosity (*first revision*)
1866 : 2017	Mineral Insulating Oils in Electrical Equipment — Supervision and Maintenance guidance (*fourth revision*)
2026 (Part 2) : 2010	Power Transformers : Part 2 Temperature rise (*first revision*)
6792 : 2017	Insulating liquids — Determination of the Breakdown Voltage at Power Frequency — Test Method (*second revision*)
6855 : 2017	Method of sampling for insulating liquids (*second revision*)
12422 : 2017	Unused Hydrocarbon—Based Insulating Liquids—Tests methods for evaluating the oxidation stability (*first revision*)
13236 : 2013	Insulating liquids — Methods for counting and sizing particles (*first revision*)
13631 : 2017	Detection and determination of specified additives in mineral insulating oils (*first revision*)
15668 : 2006	Mineral insulating oils — Methods for the determination of 2-furfural and related compounds
16082 : 2013	Insulating liquids — Contamination by polychlorinated biphenyls (PCBs) — Method of determination by capillary column gas chromatography
16084 : 2013	Mineral insulating oils — Determination of kinematic viscosity at very low temperatures
16086 : 2013	Insulating liquids — Determination of the Dielectic Dissipation factor by measurement of the conductance and capacitance — Test method
16310 : 2017	Insulating liquids Test method for detection of potentially corrosive sulphur in used and unused insulating oil.
16497 (Part 1) : 2017	Test methods for quantiative determination of corrosive sulphur compounds in unused and used insulating liquids : Part 1 Test method for quantitative determination of dibenzyldisulfide (DBDS)
IEC 60247 : 2004	Insulating liquids — Measurement of relative permittivity, dielectric dissipation factor (tan ä) and d.c. resistivity
IEC 60628 : 1985	Gassing of insulating liquids under electrical stress and ionization
IEC 60814 : 1997	Insulating liquids — Oil impregnated paper and pressboard — Determination of water by automatic coulometric Karl Fischer titration
IEC 60867 : 1993	Insulating liquids — Specification for unused liquids based on synthetic aromatic hydrocarbons
IEC 62021-1 : 2003	Insulating liquids — Determination of acidity — Part 1: Automatic potentiometric titration
ISO 6247 : 1998	Petroleum products — Determination of foaming characteristics of lubricating oils
ISO 14596 : 2007	Petroleum products — Determination of sulfur content — Wavelength-dispersive X-ray fluorescence spectrometry
ASTM D971	Standard test method for interfacial tension of oil against water by the Ring method
ASTM D4294	Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
ASTM D7150	Standard Test Method for the Determination of Gassing Characteristics of Insulating

IS/International Standard No.	*Title*	*IS/International Standard No.*	*Title*
	Liquids Under Thermal Stress at Low Temperature		sulphoxide extraction refractive index method
IP 346	Determination of polycyclic aromatics in unused lubricating base oils and asphaltene free petroleum fractions — Dimethyl	DIN 51353	Testing of insulating oils: Detection of corrosive sulfur — Silver strip test

ANNEX B

(*informative*)

(*Clause* 6.10)

POTENTIALLY CORROSIVE SULPHUR

B-1 MECHANISM OF COPPER SULPHIDE DEPOSITION

The mechanism of copper sulphide (Cu_2S) deposition is still not fully elucidated, but it may involve dissolution and transport of copper by sulphur containing species forming complexes with copper. These complexes can then be absorbed by cellulosic insulation where they decompose into Cu_2S.

The strong influence of temperature and oxygen on this process indicates that some oxidized sulphur species may be more active than those originally present in oil, or that other oxidation products are important as co-complexing agents (*see* CIGRE Technical Brochure 378). Cu_2S deposition occurs preferentially in equipment where corrosive sulphur compounds are present in oil, unvarnished or unprotected copper is used, operating temperatures are high and the amount of oxygen in oil is limited. The optimal oxygen content for copper transport seems to be relatively low, probably in the region of a few thousand µl/l, but deposition may occur over a wide range of oxygen contents.

B-2 CORROSIVE SULPHUR COMPOUNDS IN OIL

Although many sulphur compounds are known to be corrosive for copper, few have been identified as components of insulating oil. The only compound shown so far to be a potent Cu_2S forming agent and to be present in significant amounts in transformer oil is dibenzyl disulfide (DBDS). Most oils found to be forming Cu_2S contain this substance. However, refining processes using severe hydrotreatment can easily remove this reactive compound from oil. Several other substances (including disulphides, thioethers, various oxidized sulphur compounds and elemental sulphur) have been shown to cause Cu_2S formation in IS 16310 test, when added to originally non-corrosive oils.

B-3 DETECTION OF CORROSIVE SULPHUR COMPOUNDS IN PASSIVATOR-CONTAINING OILS

When oil in a transformer contains a metal passivator additive, a thin protective layer of passivator is formed on copper surfaces, preventing copper from dissolving in oil, reacting with corrosive sulphur compounds present in oil, and depositing in paper insulation as harmful copper sulphide (Cu_2S). The same occurs when testing passivator-containing oils according to IS 16310. This test method therefore cannot detect corrosive sulphur compounds present in passivating oils and may provide "false negative" results for such oils. Passivator-containing oils testing negative as new oils may then test positive and start depositing harmful Cu_2S after the additive has been consumed by aging in transformers service.

In order to detect corrosive sulphur compounds in oil containing a metal passivator additive (declared or suspected), the passivator additive has to be removed first from the oil. The two following procedures can be used for that purpose. Both are intended for newly available types of oils only, not for normal deliveries of oil.

Procedure 1

In this procedure, metal passivator additives are eliminated by specific adsorption from the oil:

a) stir 100 ml of passivator-containing oil with 500 mg of Chromabond HR-XC adsorbent (a strong, mixed-mode, polymer-based cation exchanger for basic analytes), for 1 h, then filter out the adsorbent; or

b) extract 60 ml of oil under a slight vacuum on a 3 ml column containing 200 mg of the adsorbent, if the initial concentration of passivator was < 200 mg/kg.

Procedure 2

This procedure is based on the observation that metal passivator additives in oil are consumed by oxidation aging (in accelerated tests in the laboratory and in transformers in service):

a) Run the passivator-containing oil in the test cell used in IS 12422 at 120 °C for 164 h with an air flow of 0.15 l/h to ensure that the passivator has been consumed by oxidation.

b) Test the aged oil for corrosive sulphur in the test cell of IS 16310 with new paper wrapped conductor.

c) To avoid false positives with the aged oil (that is where oxidation aging compounds of oil are mistakenly interpreted as Cu_2S), confirm Cu_2S deposition with SEM/EDX or other techniques according to Annex B of IS 16310. False positives can also be avoided by carrying out a second IS 16310 test without copper strip and with paper only, and comparing the appearance of papers after both tests with and without copper.

NOTES

1 The protective layer of passivator on copper has been observed to remain on copper after aging tests in the laboratory, but there is little knowledge on whether and how long it will remain on copper in transformers in service.

2 As a complement to IS 16310 and procedures 1 and 2 for passivator-containing oils, the quantification of corrosive sulphur compounds in oil [for example dibenzyldisulphide (DBDS) and total disulphide] can be used to ensure that none of these potentially harmful compounds are present in oil.

B-4 CONTAMINATION OF OILS

Mineral insulating oils suspected of having been accidentally contaminated with silicone oils, phthalates or other surface-active chemicals or oils should not be introduced in transformers, since these compounds can produce foaming in oil when trying to degas the transformer, thus making it difficult or impossible to fully degas the transformer oil. The foaming tendency test of ISO 6247 can be used to detect such a contamination.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards : Monthly Additions'.

This Indian Standard has been developed from Doc No.: ETD 03 (6748).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices: *Telephones*

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002 — 2323 7617, 2323 3841

Eastern : 1/14 C.I.T. Scheme VII M, V. I. P. Road, Kankurgachi, KOLKATA 700054 — 2337 8499, 2337 8561, 2337 8626, 2337 9120

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg, CHANDIGARH 160019 — 26 50206, 265 0290

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113 — 2254 1216, 2254 1442, 2254 2519, 2254 2315

Western : Manakalaya, E9 MIDC, Marol, Andheri (East), MUMBAI 400093 — 2832 9295, 2832 7858, 2832 7891, 2832 7892

Branches: AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. COIMBATORE. DEHRADUN. DURGAPUR. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. JAMSHEDPUR. KOCHI. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAIPUR. RAJKOT. VISAKHAPATNAM.

Published by BIS, New Delhi